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A general equilibrium impact study of the Emissions Reduction Fund in Australia by using a national environmental and economic model

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ABSTRACT

Several climate change policies, such as emissions trading schemes and carbon taxes, have been implemented in many countries and regions around the world. However, the current Coalition Government in Australia does not prefer such methods and has argued that these policies would substantially increase the electricity price, and weaken the Australian competitiveness and the whole economy. Subsequently, the Government replaced the carbon tax policy in July 2014 with its Emissions Reduction Fund, which fundamentally uses the government budget of A$2.55 billion to buy emission abatements from polluters. There are major arguments among the Australian public about the efficiency and the effects of this approach, but the economic effects are still unidentified. This study aims to examine the economy-wide effects of this policy on the Australian economy by employing a national environmental and economic general equilibrium model so that Australians and international audience would be aware of the impacts and how the reverse auction and carbon subsidy work as a policy to reduce emissions at large scales across all sectors in a country. Results show that Australia only experiences relatively small impact on its economy. Real GDP only declines by 0.3%–0.4% over all scenarios. Industrial and private sectors also experience relatively small unfavourable impacts, but the output and export level of the agricultural commodity will decline substantially. The renewable sectors are expanded to compensate output reductions in fossil fuel electricity generation sectors, though the expansion is insufficient to compensate for the losses.

1. Background

Both major Australian political parties, the Coalition (of the Liberal and National Parties, currently the Government) and the Australian Labor Party (the Opposition), agree on the potential climate change outcomes that are occurring mainly as a result of human activities in releasing greenhouse gas (GHG) emissions to the atmosphere.[1] These Parties also accept the national emission targets in order to reduce the national emission levels to 5% below the 2000 emission level by 2020 and to 26–28% below the 2005 emission level by 2030 (Meng et al., 2018; Nelson et al., 2018; Simshauser and Tiernan, 2018). However, the climate change policies to reduce emission levels are diverse between the current Government and the Opposition (Nong and Siriwardana, 2018b; Simshauser and Tiernan, 2018). The Australian Labor Party prefers to have a carbon price mechanism, which requires polluters to pay for their emissions, while the Coalition Government prefers a subsidy scheme whereby the Government uses the budget to buy emission abatements from polluters. When in Government the Labor Party developed plans for a carbon tax and emissions trading scheme (ETS) to enable the country to reduce its emission levels (Garnaut, 2008, 2011). Finally, under the Carbon Pricing Mechanism, the fixed carbon tax prices were introduced in July 2012 for a period of three years before moving to a flexible price periods under the cap-and-trade ETS from July 2015. However, the Carbon Pricing Mechanism was short-lived following the election of the Coalition Government in 2013 when the Carbon Pricing Mechanism was abolished in July 2014 to be replaced with the Coalition's Direct Action Plan. Under this Direct Action Plan, the Emissions Reduction Fund (ERF) scheme became the central policy, which proposes to use A$2.55 billion to buy emission abatements from polluters via

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[1] Jones (2014) and Simshauser and Tiernan (2018) noted that not all parliament members agree on the climate change issues. Recently, a new article in the Sydney Morning Herald summarises a survey indicating that 22% of One Nation Party voters and 15% of National Party voters still think that climate change was not real, though more Australians fear the effects of climate change compared to the survey results in the previous years (Hasham, 2018).

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reverse auctions (Simshauser, 2018). After six reverse auctions from 2015 to 2017, the Government has contracted to spend A$2.285 billion in order to purchase 191.7 million tonnes (Mt) emission abatements from polluters with an average price of A$11.9 per tonne of Carbon Dioxide equivalent (CO_2e) emissions. Most contracts take between 5 and 10 years to sell all emission abatements to the Government (Clean Energy Regulator, 2016). This means that the Government is only able to purchase all emission abatements by 2025.

In this context, the effects of the carbon tax and emissions trading scheme on the Australian economy have been well studied and there exists a considerable number of reports in the literature (for example, see Simshauser and Nelson (2012), Asafu-Adjaye and Mahadevan (2013), Fahimnia et al. (2013), Meng et al. (2013), Adams et al. (2014), Wolfram et al. (2016); Nong et al. (2017); and Siriwardana and Nong (2018)). However, the economy-wide impact of the ERF was quite limited. In this instance, only two studies were conducted to examine whether the ERF with the proposed budget of A$2.55 billion was adequate to enable Australia to achieve the 2020 emission target (Clarke et al., 2014; Nong and Siriwardana, 2017). Both of these studies concluded that the ERF with such a proposed budget will not enable Australia to meet the 2020 emission target. However, these two studies, that use the marginal abatement cost approach, were not able to assess the impact of the ERF on the Australian economy. Hence, a comprehensive analysis of the economic effects of the policy on the Australian economy is highly desirable.

This study will employ a static national computable general equilibrium (CGE) model to assess the economy-wide impacts of the ERF on the Australian economy and different groups of household. A social accounting matrix for Australia with details of energy sectors, emission levels, and household groups based on income levels, is utilised with this CGE model. The information on emission prices, abatement activities, budget allocation, and emission abatement delivery periods resulting from real auctions, is employed for the modelling simulations. In particular, the budget will be allocated to corresponding sectors resulting from the real reverse auctions. It is expected that this study will make a considerable contribution to the literature in both national and international perspectives. First, Australians would be aware of the potential impacts of the policy. This is because there have been arguments that the Government is using taxpayers' money to subsidise polluters to reduce their emission levels[2] but the economic impacts are still unidentified; hence, people would expect to know the likely impacts of the policy. Second, the most preferred and popular climate change policies are emissions trading schemes and carbon taxes, which have been implemented in many countries and regions around the world (Nong and Siriwardana, 2018a; Simshauser, 2018). Hence, numerous studies have been conducted to examine the impacts of these policies in various contexts. On the other hand, the reverse auction to buy emission abatements at a large scale such as at the country level has not been introduced elsewhere, except in Australia. In addition, studies of such a method to buy emission abatements at small scales are also scant. Consequently, international audiences may gain new knowledge through the findings of this study, especially how a reverse auction and carbon subsidy will work as a policy to reduce emissions at large scales across all sectors of a country. Third, a CGE modelling approach developed in this study to examine the impacts of the reverse auction to buy emissions would provide useful information for economic modellers in order to study similar issues in other countries or regions.

Subsequently this paper is organised as follows. Section 2 provides a review of the Australian subsidy policy and auction scheme. Section 3 describes the model, data, and scenario design. Section 4 provides the results and discussion, while Section 5 highlights the concluding remarks.

2. The Australian subsidy policy and auction study

In each reverse auction under the ERF scheme, bidders need to register their projects in order to bid. The registered projects will include the amounts of emission abatements, associated costs (i.e., Australian dollars per tonne of CO_2e), and periods for delivering emission abatements. The bidders will use appropriate methods provided by the Government to calculate potential emission abatements from their baseline emission levels under the business-as-usual scenario. In each auction, the Government awards projects with auctioned prices below 20% of the confidential benchmark price set by the Government. The ERF scheme also includes a safeguard mechanism that does not allow any sectors to emit higher emission levels than their business-as-usual levels.[3] From April 2015 to December 2017, the Government has successfully organised six reverse auctions. Of these, the Government has committed to purchase 191.7 Mt of CO_2e from 438 projects with a cost to the Budget of A$2.285 billion. As a result, the average price of emission abatements across auctions is A$11.9 per tonne of CO_2e emissions and all abatements must finally be delivered within 5–10 years.[4]

The reverse auction has been used widely in many different areas and not only in Australia, and relevant issues have been studied in many research projects. However, studies of reverse auctions designed to buy emission abatements are extremely scant, particularly at a large scale. Sometimes, it occurs in an indirect format and at small scales, for example, a reverse auction was designed to ask farmers not burning the residuals from harvested farms to curb the emissions released (Pant, 2015). In general, this method is considered an effective tool to set desired prices and to improve the efficiency of resource allocation when demand and supply are not able to find an effective equilibrium price. Such failure in determining the market equilibriums may be the result from intangible costs, strategic behaviour, and asymmetric information (Brown et al., 2011). In a reverse auction, bidders will bid to sell their commodities associated with proposed prices. An organiser will buy commodities from low to high prices, depending on its budgets. In order to meet the target that buys expected amounts of commodities with limited budgets, it is important to set an effective benchmark price, which is the maximum price the organiser is willing to pay when bidding for commodities. As a result, information about the costs and benefits are particularly important to have successful reverse auctions. Such information needs to be provided adequately to bidders or sellers, as in many fields, they are not particularly aware of *costs* in keeping commodities rather than selling them, as well as the *benefits* from selling these commodities. This happens commonly when dealing with farmers or villagers, who have little knowledge about the products organisers want to buy from them.

Jack et al. (2009) indicated that farmers in Indonesia have limited knowledge about the private costs of soil erosion and about the benefits from conservation activities. Similarly, Pant (2015) showed that farmers in Nepal are not aware of the private costs

[2] https://www.australiangeographic.com.au/topics/science-environment/2013/09/opinion-australias-step-back-on-climate-change/.

[3] http://www.environment.gov.au/climate-change/government/emissions-reduction-fund/about/safeguard-mechanism.

[4] http://www.cleanenergyregulator.gov.au/ERF/Auctions-results/December-2017.

from burning the residuals from harvested farms, as well as the benefits from selling residuals to the government. In addition, in instances where they expect to sell their commodities to middlemen, how they set a price per unit of commodities in an auction is still a major problem. Hence, all involved need to provide adequate information about the benefits and costs, as well as the procedures in the auctions so that these farmers and concerned others may receive expected results in such auctions. Organisers may also need to provide adequate training courses for farmers or bidders in order to perform well and effectively in the auctions. Several studies show that farmers who are trained well and are provided with adequate information will have incentives to participate in the auctions and place bids at effective prices (Kroeger and Casey, 2007; Pant, 2015; Stoneham et al., 2003). Fraser (1995) showed that farmers might gain economic rent as a result of receiving adequate information and training from auctioneers. That is, farmers can become aware of the benefits and costs when they participate in the auctions. Such information, when provided helps to reduce information rent and costs of conservation when performing highly competitive bids (Hailu and Schilizzi, 2004; Latacz-Lohmann and Van der Hamsvoort, 1997, 1998).

There are two common forms of a reverse auction: a single-unit and multi-unit auctions. A single-unit auction allows bidders to sell their commodities at a fixed price per unit of the commodities, while a multi-unit auction allows bidders to sell various quantities of their commodities at different corresponding prices (Alsemgeest et al., 1998; Hailu and Thoyer, 2006; Kagel and Levin, 2001; List and Lucking-Reiley, 2000). Of these, a multi-unit auction is more efficient than a single-unit auction by avoiding the 'lumpy bid' problem (Hailu and Thoyer, 2006; Tenorio, 1993).

The ERF scheme in Australia acts as single-unit auction, which is divided into multiple stages for the auctions. In each reverse auction under the ERF scheme, the organiser does not only deal with a group of bidders (e.g., a group of farmers), but multiple bidders who are equipped with advanced knowledge, since these bidders come from all industries in the economy. In addition, the ERF scheme is divided into many auctions with different confidential benchmark prices; hence, the Government can direct bidders step by step through various auctions so that the Government may achieve the expected results for emission abatement purchased. For example, unsuccessful bidders in a particular auction may think their bid to sell their emission abatements was at a relatively high price; hence, they would reduce their bidding prices in the next rounds of auctions. In any case, the outcomes depend on the real potential abatement costs in the economy because the Government cannot buy cheap emission abatements if all biddings are at relatively high prices. For the benchmark prices to play a real role in the auctions, the Government may set relatively low confidential benchmark prices in the first few auctions in order to discover the reactions of bidders and to examine how much emission abatements they can purchase. Fortunately, the auction prices have been relatively low in Australia, associated with considerable emission abatements. Hence, the benchmark prices in the forthcoming auctions would be similar to the prices set in the previous auctions. In the event of the benchmark prices playing no roles in auctions, as such prices are confidential, the Government can still buy emission abatements at relatively low prices. For example, the Government may have had less information about the abatement costs and initially set a relatively high benchmark price in the first auction. If they see the auction prices are low with potentially considerable emission abatements as happening in the reality, the Government can still decide how much emission abatements they want to purchase at the price levels they expect while ignoring the benchmark price set previously. In either case, the Australian Government is buying substantial emission abatements at relatively low prices.

3. Model and simulation design

3.1. Model and database

This study employs a static CGE model based on the ORANI-G model (Horridge et al., 2000) to assess the economy-wide impact of the ERF, ceteris paribus. The model incorporates economic theory and various assumptions to describe the relationships and reactions of all agents in an economy. It is assumed in the model that markets are operated with perfectly competitive mechanisms; industrial sectors attempt to minimise their costs subject to current technology; and households seek to maximise utilities based on their budget constraints. There are also market clearance and zero profit conditions in all markets. Based on these assumptions, industries use labour, capital, intermediate inputs produced by other industries, and other resources to provide their outputs. Households have incomes from labour supply, while the government has revenues from collecting taxes, such as income, sales and production taxes. It is noted that the model is assumed to have a balance condition in the labour market where labour demand is always met by labour supply and the economy is currently in an equilibrium status; any changes in either demand or supply sides will require corresponding changes in the other side to keep the market in equilibrium with a potential new equilibrium price. In addition, households and government act as final consumers in the model. The government may also provide subsidies to households and industrial sectors. In this single country model, imports and exports are also modelled to trade with the rest of the world.

While the main structure of the model is retained there are several improvements that enhance the capacity for environmental policy analysis. In particular, the production structure is modified according to Nong et al. (2017). This modified production structure allows substitution between energy sources; hence, the economy is more flexible in reacting to changes in prices of inputs. That is, industrial sectors are able to substitute resources at low input prices for those with relatively higher input prices. On the other hand, the modified production structure allows industries to use practical technologies in substituting energy inputs, since these sectors are likely to use lower input costs to substitute for higher input costs when prices of inputs change.

Fig. 1 outlines the production structure of industrial sectors in the modified ORANI-G model. In Fig. 1 (a), the commercial electricity sector or the electricity distribution sector demands of the electricity composite from various types of electricity generation via the Constant Elasticity of Substitution (CES) function. Such a structure allows this sector to select electricity inputs at least cost based on relative price changes of different electricity sources. At the top level, the sector selects inputs (i.e., electricity composite, other intermediate inputs (non-energy inputs), and primary factor-energy composite) via the Leontief function. That is, these inputs are selected at fixed proportional levels as shown in the database. The primary factor-energy composite is selected between land, labour, and capital-energy composite via the CES function. At the lower levels of CES functions, each composite commodity is selected from corresponding inputs. As a result, this electricity distribution sector is able to produce outputs at least cost.

The production structure of other industrial sectors shown in Fig. 1 (b) is slightly different from the structure of the electricity distribution sector in Fig. 1 (a). That is, the other industrial sectors do not directly make demands for electricity from generators, but from the electricity distribution sector (Fig. 1 (b) shown in green). Of these, the electricity distribution sector provides the commercial electricity commodity to be used by other sectors. This commercial

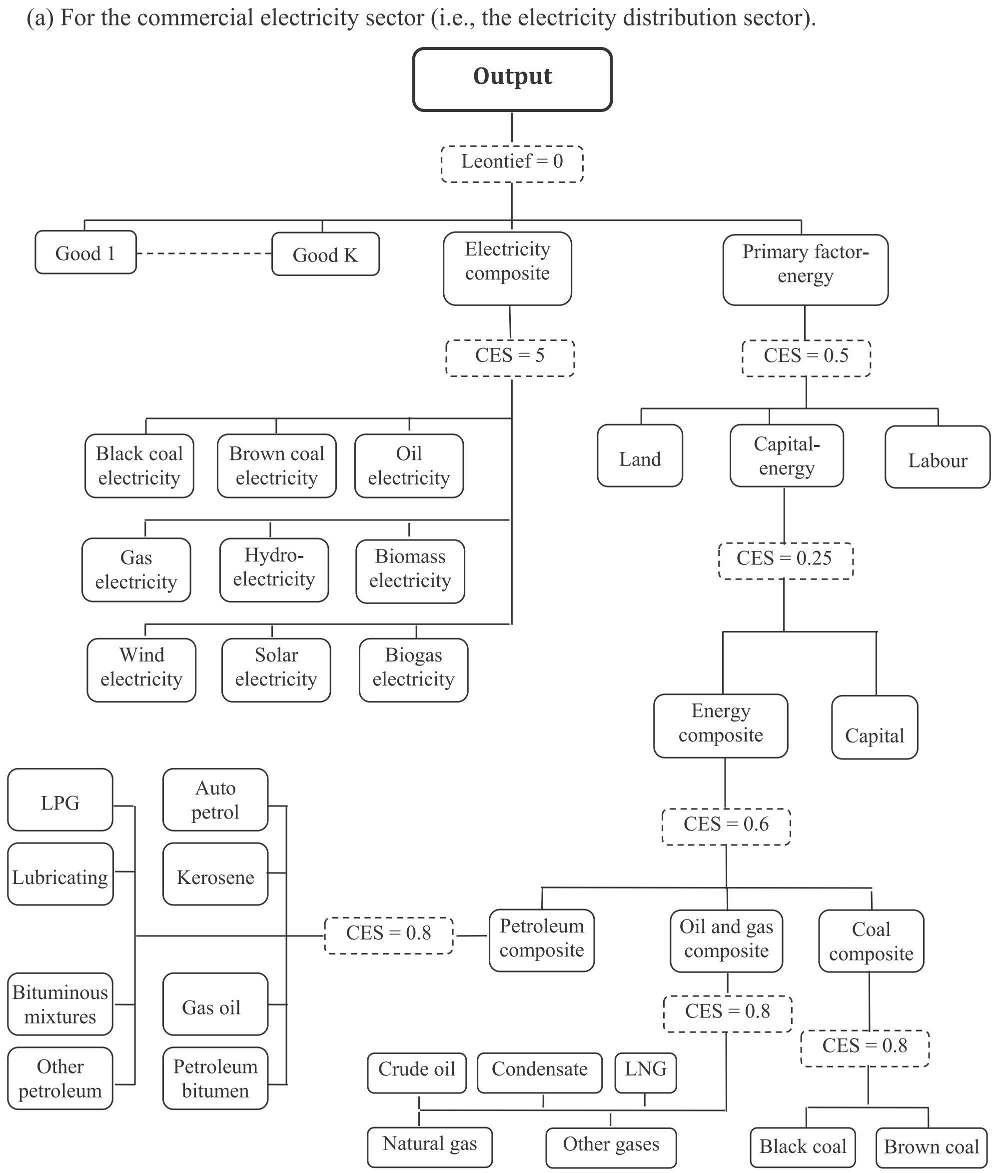

Fig. 1. The production structure in the modified ORANI-G model.

electricity commodity is nested with other energy composites via the CES function. In addition, the processes for selecting other inputs are similar to those for the electricity distribution sector.

In the model, the household sector is also divided into multi-household groups according to their income levels. In addition, the model incorporates the emission level variables for analysis of climate change policies. There are two types of emission levels: stationary and activity emissions. Stationary emissions are tied with input levels, while activity emissions are tied with output levels. Based on the information provided by the Australian Department of the Environment and Energy related to the national greenhouse gas inventory,[5] stationary emissions are divided into emissions released from the private sector, industrial sector and public sector subject to their usages of energy and chemical inputs.

[5] http://ageis.climatechange.gov.au/.

These emission levels are tied with input uses by each corresponding sector. Activity emissions including fugitive emissions and other emissions released during the production processes will be tied with output levels of corresponding industrial sectors.

In all equations that determine the relationships between the emission levels and input/output levels, there are technical change variables that are naturally exogenous (e.g., see eqs. A1–A4 in Supplement A). As a result, the emission levels can be exogenously changed when necessary if swapped with the technical change variables. In addition, there is a price on emissions that is exogenous in the model. In order to examine the effects of the ERF on the Australian economy, a subsidy variable is added in the model, which is determined as follows.

$$SUBSIDY(j) = [CO2EQ(j) - CO2ET(j)]*PRICE(j) \quad (1)$$

where j = industrial sectors; SUBSIDY is the money transfer from

(b) For other sectors.

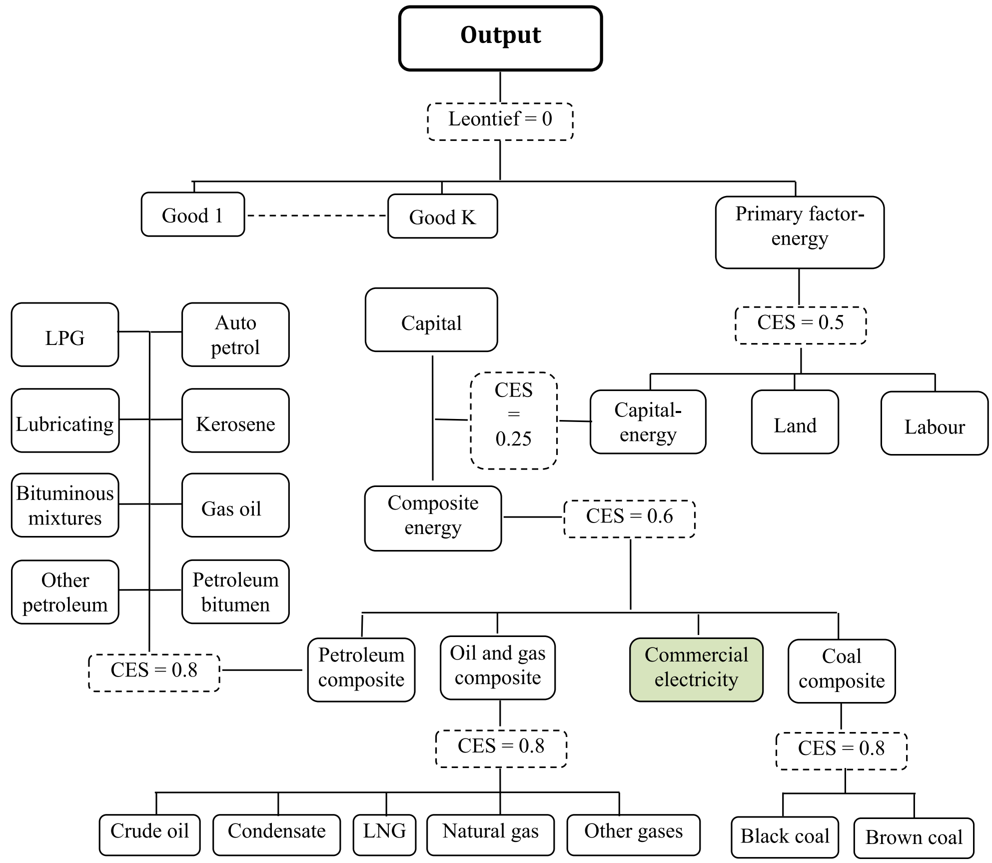

Fig. 1. (*continued*).

the government to the corresponding industry j for their emission abatements; CO2EQ is the industry's initial emission level in the baseline; CO2ET is the industry's emission level after receiving a subsidy from the government for their emission abatements; [CO2EQ - CO2ET] is the emission abatement; and PRICE is the price on emissions that the government is willing to pay to industrial sectors for each unit of emission abatements.

Data used for this model comprises of input-output (I-O) data, greenhouse gas emission data, and data in the household expenditure survey. The I-O data includes the Australian I-O Tables 2008–09 and the I-O product details Tables 2008–09 published by the ABS (2012a, 2012b). The I-O tables provide the information of production levels, inputs, taxes, and margins at aggregated levels of industries and commodities, while the I-O product details table has more detailed information of the industries and commodities at disaggregated levels. These two sets of tables are used to provide the input-output data for the model, as well as to disaggregate four energy sectors into 24 sub-energy sectors (Fig. 1). The household expenditure survey (HES) 2009–10 provided by the ABS (2014) is used to disaggregate households into 10 groups according to their income levels. The national greenhouse gas inventory 2009 (Department of Climate Change, 2013) is used to construct the emission matrixes: the stationary emission matrix tied with input uses, and the activity emission matrix tied with output levels. The main reason for using the 2008–09 I-O data is to use all compatible databases. The I-O tables, the I-O table (product details), and the national greenhouse gas inventory are published every year with a three-year lag of the databases from the released year. By contrast, the HES is published discretely. The most two recent HESs are the HES 2009–10 and HES 2015–16. The HES 2015–16 was released a couple of months ago. Hence, the most practical compatible databases were the database in 2009, given a long period for database compilation. Furthermore, the behaviour parameters are provided by Meng et al. (2013) as shown in Fig. 1.

3.2. Simulation design

Since this study examines the impact of the ERF when total funding of A$2.55 billion is expended to buy emission abatements, and most contracts to sell all emission abatements are within 5–10 years; hence, all funding is likely to be released by 2025. As a result, the database is updated from 2009 to 2025. Table 1 shows the growth rate projections of selected variables from 2009 to 2025. For growth rates in 2009–2017, population is collected from the ABS (2018a), the exchange rate is collected from the Reserve Bank of Australia (2018), and other indexes are collected from the ABS (2018b). Growth rate projections of these variables in 2018–2025 follow Asafu-Adjaye and Mahadevan (2013). In general, the model

Table 1
Growth rates in 2009–2025 (percentage change).

Population	24.5%
Real import	50.2%
Real investment	40.6%
Real private consumption	80.8%
Real public consumption	84.2%
Real export	50.6%
Exchange rate (AU$/foreign currency)	−16.8%

Table 2
Committed emission abatements by industries (million tonnes).

Activities	Industries	Emission abatements with A$2.285 billion	Emission abatements with A$2.55 billion	Funding allocation (A$ billion)
(1)	(2)	(3)	(4)	(5)
1. Waste	- Waste treatment	24.5	27.3	0.325
2. Vegetation	- Agriculture	124	138.4	1.650
3. Agriculture		17.8	19.9	0.237
4. Savanna burning		13.8	15.4	0.184
5. Industrial fugitives	- Black coal mining	5.6	6.2	0.074
	- Brown coal mining			
	- Oil extraction			
	- Condensate extraction			
	- LNG extraction			
	- Natural gas extraction			
	- Other gas extraction			
6. Energy efficiency	- All industries	4.7	5.2	0.062
7. Transportation	- Transportation	1.2	1.3	0.015
- Total		191.7	213.8	2.55

Note: Emission abatements in column (3) are the result from six reserve auctions released on 14 December 2017, where the Government committed to spend A$2.285 billion to buy 191.7 million tonnes of CO_2e emissions. Emission abatements in column (4) are proportionally calculated when the Government spends all funding of A$2.55 billion (it is assumed the average price of emissions of A$11.9 is remained for future auctions).

is simulated by exogenously shocking the variables shown in Table 1; then all endogenous variables, for example, related to industrial outputs, consumptions, emission levels, incomes, etc., will be determined. In addition, the database will be updated to capture such changes in the economy. That is, such an updated database eventually represents the Australian economy in 2025 based on the projected assumptions. This is the baseline scenario, which does not include reverse auction simulations.

Table 2 summarises the auction results between April 2015 and December 2017. Column (1) shows a summary of emission abatements from main activities, while these activities are manually mapped to corresponding sectors in column (2) based on the industrial information in the I-O tables published by the ABS (2012a) and the sources of emissions in the national greenhouse gas inventory published by the Australian Department of Climate Change (2013). Column (3) shows committed emission abatements from each activity or industry when the total abatement purchase is worth of A$2.285 billion. In column (4), emission abatements shown for each industry or activity are projected when the Government uses all funding of A$2.55 billion to buy emission abatements. In the past six auctions, the Government has committed to spend A$2.285 billion to buy 191.7 Mt of CO_2e at the average price of A$11.9 per tonne of CO_2e emissions. It is assumed in this study that the Government continues to buy further emission abatements from each activity at this average price until all funding of A$2.55 billion is allocated. Hence, the emission abatements in column (4) are projected proportionally according to the emission abatements in column (3) and the corresponding allocated funding (i.e., A$2.285 billion and A$2.55 billion). Column (5) shows the funding received by each industry in column (2) for their emission abatements shown in column (4).

The emission abatements are exogenously shocked in the model for the emission level variables in the corresponding industries so that each corresponding industry in column (2) reduces emissions levels at fixed amounts of emissions abatements shown in column (4). The price of emissions is also shocked at A$11.9 per tonne of CO_2e. It is also noted that each industry or auctioneer bids emission abatements at different prices in the real auctions. The price of A$11.9 per tonne of CO_2e is only an average price. The price for each awarded project is not publicly reported[6]; hence, it is assumed that every industry receives the average price per tonne of CO_2e for each tonne of CO_2e emission abatements. In addition, the funding is allocated or paid to industries over time to buy their emission abatements. However, the Government does not publicly or explicitly announce the funding allocation and emission abatement each year. In addition, this study uses a static CGE model for analysis; hence, it is assumed that all funding will be released to buy all emission abatements by 2025.

It is also assumed in the simulation that the subsidies are not windfalls, as the emission levels are exogenously shocked. Recipient sectors need either to lower their production levels or to invest more on abatement capital or technologies to improve their efficiency, thereby being able to reduce emission levels that are sold to the Government. Since production levels are at the optimal levels to help firms to maximise their profits, this approach would be costly and would not be an optimal strategy for firms to reduce their emission levels for auctions. On the other hand, the method that invests on abatement capital or technologies in order to lower the emission levels is widely used or discussed (Fischer, 2008; Suk et al., 2016; Venmans, 2016; Whittington and Lynch, 2015; Zhao, 2003). It is also noted that investments could be allocated to improve the productivity of other endowment factors, such as labour. However, the emission levels may increase eventually because improvements of labour productivity would result in higher levels of production. As a result, while all other things, such as energy efficiency and/or technologies, are unchanged/constant, improvements of labour productivity would increase the emission levels. It is therefore assumed in this study that the recipient sectors will need to spend more money to invest on abatement capital or technologies in order to enable them to reduce their emission levels to sell to the Government.

Although a specific amount of investment on abatement capital or technologies by each individual sector is not known, it is assumed to be equal to the funding received from the Government for the committed emission abatements. It is likely to have had a neutral impact on industrial sectors in the short run, but industrial sectors will have been equipped with advanced or cleaner technologies that are able to help them to only release low emission levels in the long run. As a result, in the model, industries invest more on abatement capital with the amounts equivalent to the subsidy amounts received from the Government for their emission

[6] The average price was A$13.95 in auction 1, A$12.25 in auction 2, A$10.23 in auction 3, A$10.69 in auction 4, A$11.82 in auction 5, and A13.08 in auction 6. It can be seen that the fluctuations of the average prices are unpredictable, but they are very close to each other because the Government sets the benchmark price in each reverse auction at the price the Government expects to buy emissions abatements.

abatements. For example, as shown in Table 2 if the agricultural industry is able to reduce 173.7 Mt of CO_2e (=138.4 + 19.9+15.4) to receive A$2.071 billion (=173.7*11.92) from the Government, this industry needs to spend A$2.071 for investment on capital so that it is able to reduce emission levels by 173.7 Mt of CO_2e. In the modelling simulation, it is assumed that it will change the capital augmenting technical variables of corresponding industries by the percentages equivalent to the ratios of subsidy receipts to capital values of these industries. Coupled with such investment information on abatement capital, the study also examines three different assumptions about the sources for the funding of A$2.55 billion.

In Scenario 1, it is assumed that total funding of A$2.55 billion is currently in the Government budget, which is not used for other purposes and there is no need to recoup the budget. Hence, it is simply deduced from the government revenue (for example, see equation B7 in Supplement B).

In Scenario 2, it is assumed that release of the funding of A$2.55 billion needs to be recouped eventually and it is sourced from increasing the production tax, which is equivalent to the subsidy received by each industry. For example, industry A that receives a funding of A$10 million would bear an increase in its production tax of A$10 million. In this scenario, it is assumed that the funding plays a neutral role, since the funding received is equal to the increased production tax faced by each sector. This approach may be similar to the implementation of a command-and-control regulation; however, this would only happen in the short run. Industrial sectors and the whole economy may gain substantially from such investment activities in the long run. For example, the whole society will benefit from a cleaner environment. The industrial sectors will be equipped with cleaner technologies through such investments that will enable them to release low emission levels in the long run. In this context, as other countries are increasing their commitments and obligations to reduce emission levels (e.g., see the Copenhagen Agreement in 2009 and Paris Climate Agreement in 2015), there might be stronger and tighter climate change and energy policies to force industrial sectors to reduce their emission levels in the near future. Hence, cleaner production technologies in the Australian sectors would help them to lower their emission cost burdens in the future in such a tightening international context.

Scenario 3 assumes that this funding is also sourced from increasing the production taxes on each industry (excluding the renewable electricity generation industries); however, such a tax increase would be based on the shares of the current production tax rates for each industry. If the current tax for industry A is small, the production tax increase for this industry is relatively small and vice versa.

It is noted that these three scenarios are proposed in the context that there are no specific discussions about the sources of funding in reality. There have been arguments that the Government is using taxpayers' money to subsidise polluters to reduce their emission levels as noted previously. It seems as though the Government is using their tax revenues for emissions purchasing. That is, it is similar to the case in Scenario 1 proposed in this study. For Scenario 2 and Scenario 3, given the fact that there is no announcement by the Government that they will increase taxes to compensate for the ERF spending, this study proposes several potential scenarios to examine the impacts if the Government goes in such directions. This is because they may need to recoup such expenditure in their budget in the future though it is not announced in advance. There are several ways to increase taxes. For example, the Government can increase the income tax, consumption tax, or production tax. Such measures are likely to be controversial in the Australian public domain if Government was seen to be using taxpayers' money to pay polluters. It is especially likely that the public would not accept increased income or consumption taxes for such compensation. Hence, increasing production tax may be the optimal way to recoup the funding expense if the Government wants to recoup the budget.

In addition, the simulation is run with a short run closure. That is, the real wage rate and capital stock are fixed but capital is allowed to move between industries, while the employment level and rate of return on capital are endogenously determined after running the simulation.

4. Results and discussion

This section describes the impacts of the ERF on the Australian economy over different scenarios. In particular, the results reported in this section are the deviations/differences in the short run between the policy scenarios and the baseline projection in 2025. Macroeconomic results are provided in advance, followed by the results on key sectors.

4.1. Macroeconomic impact

Table 3 shows some key macroeconomic effects on the Australian economy in three different scenarios when the Australian Government spends all of their funding of A$2.55 billion to buy emission abatements from polluters. In general, the Australian economy only experiences small contractions because the cost of emission abatement is relatively small. That is, the average price per tonne of CO_2e is only A$11.9, which is only about half of the carbon price of A$23 in 2012–13 and A$24.15 in 2013–14 under the Carbon Price Mechanism introduced by the former Labor Government. Under the carbon tax of A$23 per tonne of CO_2e introduced in 2012, Meng et al. (2013) estimated that the Australian economy would experience a reduction in real GDP by 0.59%. The auction price of A$11.9 would therefore indicate that the ERF scheme may encourage polluters to invest more on cleaner production technology in order to reduce their emission levels to receive the subsidy from the Government.

The unfavourable effects on the Australian economy are shown to increase in terms of the absolute values over Scenario 1, Scenario 2, and Scenario 3. This is because industries in Scenario 1 do not bear any increased production tax on their production processes since the Government does not need to recoup their funding. On the other hand, industries in Scenario 2 and Scenario 3 suffer increased production taxes, as the Government is assumed to recoup its allocated funding by increasing the production taxes. Hence, the costs on the Australian economy in these two latter scenarios are higher than the costs in Scenario 1, leading to higher unfavourable impacts on the economy. The Australian economy will contract at a relatively higher rate in Scenario 3 than it in

Table 3
Macroeconomic impacts compared to the baseline in 2025 (percentage change).

Variables	Scenario 1	Scenario 2	Scenario 3
Consumer price index	0.12	0.16	0.24
Price of electricity	0.12	0.19	0.66
Rate of return on capital	−0.16	−0.3	−0.43
Employment	−0.32	−0.46	−0.56
Real public consumption	−0.18	−0.22	−0.38
Real private consumption	−0.02	−0.03	−0.05
Total equivalent variation (A$ million)	−196.64	−236.25	−422.78
Real investment	−0.18	−0.22	−0.38
Terms of trade	0.13	0.15	0.23
Real export	−1.13	−1.31	−1.39
Real import	−0.18	−0.22	−0.29
Real GDP	−0.3	−0.35	−0.39
Real GNE	−0.09	−0.11	−0.19

Scenario 2 because the increased production taxes are different between these two scenarios. In particular, in Scenario 2 when an industry receives funding for its emission abatements, it also suffers an increased production tax on its production level, which is equal to the funding they receive. Hence, average effects on every sector are relatively small because sectors with small emission abatements only suffer small increases in the production taxes. On the other hand, production taxes are increased for every industry to fulfil the Government allocated funding of A$2.55 billion; such increased taxes are based on industries' shares of the current production taxes no matter to what extent they reduce emission levels in order to receive the funding or not. This causes some industries that reduce relatively small rates of emission levels to receive small amount of funding or those industries that do not reduce emission levels also suffer increased production taxes. As a result, some industries that are not subject to suffer increased production tax rates or only suffer small increased production tax rates in Scenario 2 now have to bear higher increased production tax rates in Scenario 3. Obviously, the total production tax collected in both scenarios is A$2.55, the tax collection is only transferred from this industry to other industries. However, the production shares and the production tax rates are different between industries, leading to increased tax rates on this set of industries having relatively higher unfavourable effects than the effects from increasing tax rates on a set of other industries. As a result, the Australian economy experiences relatively higher unfavourable impact in Scenario 3 than the impact of Scenario 2, though the differences are small.

In detail, total capital in the economy is fixed in the short run, capital is only allowed to move between industries. Hence, industries face relatively high challenges in the short run to reduce substantial emission levels based on the investment on abatement capital. In addition, many sectors, such as agriculture, mining, and extraction sectors, contain most emissions from their production activities. Hence, many sectors need to reduce their production levels in order to lower their emission levels. Consequently, the supply prices would increase, leading to increased consumer price index of 0.12% in Scenario 1. Additional increases in the production taxes in Scenario 2 and Scenario 3 result in higher consumer price indexes of 0.16% and 0.24%, respectively, due to increased costs on the production activities. Similarly, the electricity generation sectors, particularly the main generators such as the fossil fuel electricity generation sectors, also reduce their production levels, leading to increased electricity prices.[7] In Scenario 2 and Scenario 3, these electricity generation sectors also suffer increased costs due to increases in the production taxes, leading to higher reduction rates in their production levels. Consequently, the electricity price increases at relatively higher rates than the increase of the price in Scenario 1. For example, the electricity price in Scenario 2 and Scenario 3 increases by 0.19% and 0.66%, respectively, while it increases by 0.12% in Scenario 1. In addition, the increased production taxes for these fossil fuel electricity generation sectors are higher in Scenario 3 than the increases in Scenario 2. Hence, these electricity generation sectors would experience higher unfavourable impact in Scenario 3 than those in Scenario 2. It results in a higher price for electricity in Scenario 3 than the price increase in Scenario 2.

Since capital-augmenting technical changes increase in all abatement subsidising sectors and capital is mobile between industries, all industries will face the same price for capital. Such increased capital-augmenting technical changes lead to a reduction in the capital price. It is also noted that all industries face the same unit cost of capital because capital is able to move between industries. In this case, the unit cost of capital will slightly increase because of increased demands for capital. As a result, the rate of return on capital in percentage change form, which is measured as the difference between the capital price and unit cost of capital, will eventually decline. In this instance, the rate of return on capital slightly reduces by 0.16% in Scenario 1, while it declines by 0.3% and 0.43% in Scenario 2 and Scenario 3, respectively due to higher costs. The effect is small over all scenarios because the amount of A$2.55 billion invested in the new capital is relatively small compared to the capital stocks in each industry. In addition, the increased production tax worth of A$2.55 billion is also small relative to the current production tax levels, as well as the level of the Australian GDP (i.e., about 0.2% of the Australian GDP).

Under the subsidy scheme, the employment level is also unfavourably affected because the real wage rate is fixed in the short run; hence, the price of labour will increase at the same rate as the consumer price index, that results from contracted production levels. Such increases in the price of labour lower the demands for labour. Consequently, the aggregated employment level declines by 0.32% in Scenario 1, while it declines by 0.46% and 0.56% in Scenario 2 and Scenario 3, respectively.

Real private consumption will only slightly declines by 0.02% in Scenario 1, 0.03% in Scenario 2, and 0.05% in Scenario 3 though the consumer price index changes at relatively higher rates in terms of absolute values. In ORANI-G, the total real private consumption is modelled as an aggregated level of supernumerary and subsistence demands (see equation B10 in Supplement B). Subsistence demand is dependent on the numbers of households and taste changes, which are not changed in the modelling simulations (see eq. A8 in Supplement A). Supernumerary demands are changed subject to the price of commodities (see eq. A9 in Supplement A) and such supernumerary demand changes are at relatively high rates after running the simulations, but such changes are still relatively small. In addition, the ratio of supernumerary demand to total expenditure is small. As a result, total real private consumption only changes at small rates. On the other hand, the real public consumption is changed mainly due to the price levels. For example, the real public consumption declines by 0.18%, 0.22%, and 0.38% over the three scenarios, respectively. Total equivalent variation measured in dollar values also declines by small amounts over all scenarios due to slight increases in the consumer price index. Aggregated real investment declines by 0.18 in Scenario 1, 0.22% in Scenario 2, and 0.38% in Scenario 3 because the cost of investment increases. The higher reduction rates in Scenario 2 and Scenario 3 are due to higher costs in these two scenarios.

The terms of trade, which is measured as the differences between the average export price and average import price in terms of percentage change form, will have improved by 0.13% in Scenario 1, 0.15% in Scenario 2, and 0.23% in Scenario 3. This is because the overall price in the Australian domestic market increases in these scenarios, while the world market prices are assumed to be constant in the model because Australia is a relatively small economy, which is rarely likely to affect the world prices of commodities. This improvement in the terms of trade is likely to affect exports and imports of Australia on the world market, leading to a downgrade in the country's trade balance. In this context, Australia's exports will be reduced by 1.13% in Scenario 1 due to increased prices of exported commodities. This reduction is 1.31% and 1.49% in Scenario 2 and Scenario 3, respectively. The country's imports also slightly decline by 0.18% in Scenario 1, 0.22% in Scenario 2, and 0.29% in Scenario 3 because lower production levels in the domestic market lead to reduced demands for intermediate inputs, including demands for commodities from the international market. Consequently, the unfavourable impacts on real consumption, investment, and net exports lead to a reduction in real GDP by 0.3%, 0.35%,

[7] It is noted that 80% of electricity in Australia is produced by fossil fuel plants, which therefore dominate the effects on electricity prices.

and 0.39% in Scenario 1, Scenario 2, and Scenario 3, respectively. This is a relatively small impact on the overall Australian economy, while the subsidy funding can help the country to reduce the emission levels by 213.8 Mt of CO_2e emissions. This may be tolerable for the benefit of the cost effectiveness and resource allocation efficiency that the ERF scheme brings to the country. In addition, the real gross national expenditure that sums up all consumptions and investments only declines at small rates over all scenarios.

4.2. Impact on sectors

Fig. 2 outlines the output levels of the electricity generation and distribution sectors in all scenarios. As discussed, emission abatements and associated funding received by the fossil fuel electricity generation sectors are relatively small. The increased production taxes for these sectors are also not high; hence, these fossil fuel electricity generation sectors only experience relatively low reduction rates in their production levels in all scenarios. The renewable energy sector slightly increases its output levels to compensate for the shortfalls in the output levels of the fossil fuel electricity generation sectors because there are substitution possibilities between electricity inputs. However, the expansion of the renewable electricity generation sector is not adequate to fulfil the losses in the fossil fuel electricity generation sectors, thereby leading to a reduction in the output level of the electricity distribution sector in all scenarios. This is because the fossil fuel electricity generation sectors produce most outputs of electricity.

There are also slightly different fluctuations in the output levels for these electricity generation sectors because the shocks are only different at small rates over all scenarios. For example, the production tax increases for the black coal and brown coal electricity generation sectors in Scenario 2 and Scenario 3 are only slightly different, though the tax increases in Scenario 3 are slightly higher than the increases in Scenario 2. As a result, the output level of the black coal electricity generation will decline by 0.3% in Scenario 2 and 0.7% in Scenario 3, while the reduction rate is 0.6% and 0.9% for the brown coal electricity generation sectors in these two scenarios, respectively. By contrast, the increased production taxes for the oil and gas electricity generation sectors in Scenario 2 are slightly higher than those in Scenario 3. Hence, the oil electricity generation will reduce its output level by 1.6% and 1.1% in Scenario 2 and Scenario 3, respectively, while the reduction rates are 1.3% and 1% for the gas electricity generation sector in these two scenarios, respectively. The output reduction rates for these fossil fuel electricity generation sectors in Scenario 2 and Scenario 3 are higher than those in Scenario 1 because these sectors do not suffer increased production taxes as in Scenario 1.

Fig. 2 also shows that the output level of the renewable electricity generation sector only slightly increases by 0.5% in Scenario 1, 1.2% in Scenario 2, and 2.2% in Scenario 3 in order to compensate for the increasing shortfalls in the output levels of the fossil fuel electricity generation sectors in these scenarios. As discussed previously the expansion in renewable electricity generation is not adequate to compensate the losses in the production levels of the fossil fuel electricity generation sectors because these former sectors only account for a small share in total electricity generation. Hence, the output level of the electricity distribution sector declines by 0.2% in Scenario 1, 0.3% in Scenario 2, and 0.6% in Scenario 3.

Table 4 shows the output and export fluctuations of other commodities. These sectors are the main sectors that, by reducing their emission levels will receive the funding from the Government though at small amounts. They also use the funding received for capital investment to increase their efficiency, thereby lowering their emission levels. As a result, these sectors suffer increasing costs on their production processes, leading to reductions in their output levels. Hence, most sectors shown in Table 4 reduce their output levels in Scenario 1. Of these, the agricultural sector will reduce its output level at the highest rate of 2.6% though this sector receives around A$2.07 billion out of total A$2.55 billion for its emission abatements. This is because most emission levels of this sector (i.e., 94% of total emission level of this sector) are activity emissions released from the production processes. As a result, though improvements of the capital efficiency help the agricultural sector to reduce its emission levels, the sector still needs to reduce their output level to gain emission abatements for the auctions. Consequently, this sector reduces its output levels at higher rates than those for other sectors in all scenarios. In addition, there are substitution possibilities among the groups of energy inputs as shown in Fig. 1, for example between oil and natural gas extraction commodities. Therefore, output levels of some commodities will increase to substitute for output shortfalls of other commodities in the corresponding groups. Finally the output level of the oil extraction commodity slightly increases by 0.22% to substitute for losses in outputs of other oil and gas extraction commodities.

Output levels in most sectors will contract at relatively higher rates in Scenario 2 compared to the reduction rates in Scenario 1 (except the black coal mining sector) because these sectors suffer production tax increases in Scenario 2, while there is no production tax increase in Scenario 1. The agricultural sector still experiences the highest reduction rate of 3.96% in its output level in Scenario 2 compared to the reduction rates in other sectors. Output levels of

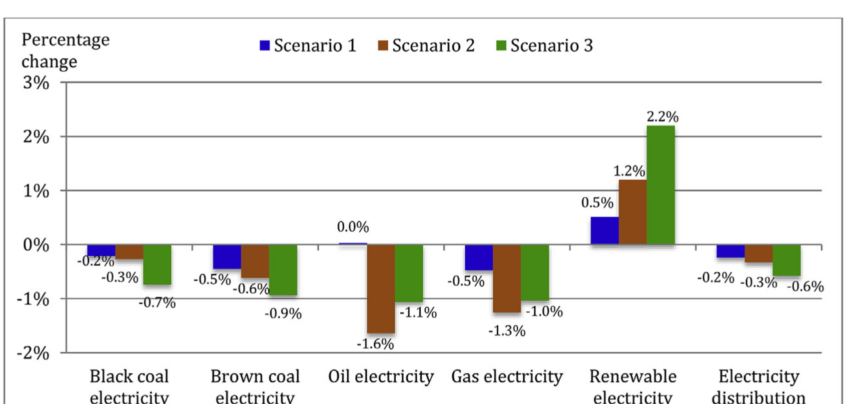

Fig. 2. Output of electricity compared to the baseline in 2025 (percentage change).

Table 4
Output and export by commodity compared to the baseline in 2025 (percentage change).

	Output			Export		
	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
1. Agriculture	−2.6	−3.96	−2.7	−11.2	−17.28	−10.83
2. Waste treatment	−0.35	−0.57	−0.51	0	0	0
3. Black coal mining	−0.09	0.32	0.66	−0.08	0.34	0.75
4. Brown coal mining	−0.37	−0.5	−0.67	−0.09	0.32	0.78
5. Oil extraction	0.22	0.9	0.98	0.84	2.17	2.22
6. Natural gas extraction	−0.63	−1.26	−1.12	−0.3	−0.55	−1.33
7. Petrol	−0.23	−0.31	−0.29	−2.72	−3.92	−3.64
8. Kerosene	−1.14	−1.58	−1.57	−2.72	−3.92	−3.64
9. Fuel oil	−0.86	−1.25	−0.97	−2.72	−3.92	−3.64
10. Transportation	−0.41	−0.49	−0.65	−0.32	−0.66	−1.43

Note: Brown coal mining and waste treatment commodities are not exported.

kerosene, oil gas extraction, and fuel oil sectors will be reduced by 1.58%, 1.26%, and 1.25%, respectively in Scenario 2, which are relatively higher than those for these other sectors. While the black coal mining sector increases its output level by 0.5% in Scenario 2. The output level of the black coal commodity increases at a higher rate of 0.66% in Scenario 3 in order to compensate for higher losses in brown coal output level of 0.67%.

In Scenario 3, output levels of some sectors will reduce at relatively higher rates compared with the reduction rates in Scenario 2, but some reduce at lower rates in Scenario 3 relative to Scenario 2. This is because the production tax increases for these sectors are different in these two scenarios. The agricultural sector particularly reduces its cost burden in Scenario 3 compared to the burden in Scenario 2. This is because the Government bases on the share of the current production tax rates to increase the production tax level in Scenario 3, while the Government increases the production tax level based on the received funding amounts in Scenario 2. As a result, the output level of the agricultural sector only declines by 2.7% in Scenario 3 compared with a reduction of 3.96% in Scenario 2. The effects on the output levels of the waste treatment and transportation sectors are also relatively small because the cost increases for these sectors are not high in all scenarios.

Table 4 also shows fluctuations of commodity exports in all scenarios. In general, fluctuations of commodity exports follow the trends of the fluctuations in the output levels, resulting from the availability of commodities in the domestic market. In addition, fluctuations of output levels also result from the changes in the supply prices of commodities, which affect the relative prices between the domestic and international markets. Higher fluctuation rates at the output levels lead to higher fluctuations in the supply prices, thereby causing the commodity exports to change at higher rates. When the output levels decline, it leads to increased prices, thereby leading to higher prices for exported commodities than these commodities in the international market. Hence, exports of commodities decline correspondingly and vice versa. The magnitudes of the effects on commodity exports are also due to the Armington elasticity of substitutions assumed in the model. In this instance, exports of the agricultural commodity are reduced at relatively high rates over all scenarios. For example, exports of the agricultural sectors reduce by 11.2% in Scenario 1, 17.28% in Scenario 2, and 10.83% in Scenario 3. Exports of petroleum products also decline at higher rates of 2.72% in Scenario 1, 3.92% in Scenario 2, and 3.64% in Scenario 3. Export of waste treatment is not reported because these commodities are not used for export. Australian transport service provided to the international market also declines by 0.32% in Scenario 1, 0.66% in Scenario 2, and 1.43% in Scenario 3 due to lower production levels, leading to higher prices of the services.

Table 5 shows the fluctuations in demands for labour, investment, and electricity by sectors. Of these, demands for labour and electricity particularly follow the trend of fluctuations in the production levels. That is, increases in the production levels lead to increases in demands for labour and electricity inputs and vice versa. Of these, the reduction rates of demands for labour and electricity by the agricultural sector are still highest relative to those for other sectors in all scenarios because this sector experiences the highest reduction rate in its production level. For example, the demands for labour by the agricultural sector decline

Table 5
Demands by industry compared to the baseline in 2025 (percentage change).

Industry	Labour			Investment			Electricity		
	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
1. Agriculture	−1.57	−4.14	−1.84	4.56	1.94	4.26	−3.63	−6.14	−4.1
2. Waste treatment	−0.91	−0.63	−0.66	2.99	2.82	2.73	−0.04	−0.3	−0.45
3. Black coal mining	−0.15	0.16	0.47	−0.29	0.14	0.33	−0.15	0.17	0.27
4. Brown coal mining	−0.43	−0.65	−0.85	−0.57	−0.67	−1	−0.44	−0.64	−1.05
5. Oil extraction	0.12	0.7	0.74	−0.06	0.64	0.55	0.15	0.75	0.61
6. Natural gas extraction	−0.61	−1.26	−1.21	−0.75	−1.32	−1.36	−0.54	−1.12	−1.38
7. Petrol	−0.3	−0.43	−0.44	−0.5	−0.53	−0.66	−0.31	−0.47	−0.71
8. Kerosene	−1.23	−1.72	−1.75	−1.43	−1.82	−1.98	−1.23	−1.74	−2.01
9. Fuel oil	−1.04	−1.53	−1.23	−1.24	−1.63	−1.45	−1.06	−1.56	−1.5
10. Black coal electricity	−0.15	−0.15	−0.75	−0.08	−0.19	−0.55	−0.21	−0.22	−1.04
11. Brown coal electricity	−0.35	−0.57	−0.91	−0.03	−0.09	−0.57	−0.43	−0.66	−1.23
12. Oil electricity	−0.04	−1.71	−1.11	−0.15	−1.5	−1.05	0	−1.76	−1.38
13. Gas electricity	−0.33	−1.13	−0.93	−0.3	−1.06	−0.93	−0.31	−1.08	−0.15
14. Renewable electricity	0.45	1.09	2.13	0.24	0.99	1.88	0.49	1.16	2.09
15. Electricity distribution	−0.29	−0.43	−0.62	−0.52	−0.56	−0.92	−0.26	−0.38	−0.71
16. Transportation	−0.45	−0.58	−0.77	−0.61	−0.63	−0.95	−0.45	−0.58	−1

by 1.57% in Scenario 1, 4.14% in Scenario 2, and 1.85% in Scenario 3, respectively, while the demands for electricity falls by 3.63%, 6.14%, and 4.1% in these three scenarios, respectively. The renewable electricity generation sector increases its demands for labour and electricity, while the fossil fuel electricity generation and electricity distribution sectors reduce demands for these commodities because of changes in their production levels.

Table 5 also shows changes in demands for investment. Similar to the demands for labour and electricity, changes in demands for investment follow the signs of changes in the production levels, except for the agricultural sector and waste treatment sector. These two sectors reduce the highest levels of emissions to receive around 94% of total funding of A$2.55 billion. That is, the agricultural sector receives A$2.071 billion, while the waste treatment sector receives A$0.325 billion from the Government for their emission abatements. To achieve these emission abatements, it is assumed that they need to invest such amounts of funding on capital to improve their efficiency. Hence, the investment demands for these sectors increase in all scenarios though their production levels fall. For example, the agricultural sector increases its demands for investment by 4.56% in Scenario 1, 1.94% in Scenario 2, and 4.26% in Scenario 3, while the increases are 2.99%, 2.82%, and 2.73% for the waste treatment in these scenarios, respectively. Other sectors are also assumed to use funding for capital investment. However, their funding receipts are relatively small, leading to increased small investment amounts on capital. In addition, the rate of return on capital falls in all scenarios, leading to reductions in the gross growth rates of capital, which is determined as the ratio of investment to capital. In the short run, total capital is fixed, while capital is mobile only between industries. As a result, increases in capital in some industries cause investments in other industries to decline. Consequently, demands for investments in some industries decline because of reduced capital stocks in these industries (see eq. A11– A13 in Supplement A).

Fig. 3 shows the changes in the equivalent variation for each household group, which is measured in dollar values. Generally speaking, reductions in the equivalent variation are relatively small in all scenarios because the overall price level only slightly increases in these scenarios. The reduction levels also increase from the poorest (group 1) to the richest (group 10) because the rich group has higher consumption levels than the poor. Of these, the equivalent variation only declines by less than A$5 million for the poorest (group 1) in all scenarios, while the equivalent variation falls by A$74 million in Scenario 1, A$86 million in Scenario 2, and A$168 million in Scenario 3 for the richest group (group 10). The effects on the equivalent variation will worsen from Scenario 1 to Scenario 2 and Scenario 3 for all household groups because costs on the economy are higher in the corresponding scenarios, leading to higher overall price levels.

5. Conclusion

This study employs a national environmental and economic CGE model to assess the impact of the ERF scheme, with a budget of A$2.55 billion, on the Australian economy. The benefits of this study are threefold. First, the potential impacts of a carbon tax or emissions trading scheme in the country have been well studied; however, the impacts of the reverse auctions are still unidentified. Hence, it is timely to inform Australians about the likely impacts of this policy. Second, the method of running reverse auctions to buy emission abatements from polluters at the country level is still new in the international context, as the popular climate change policies are carbon taxes or emissions trading schemes. Even at small scales, reverse auctions are rarely designed to buy emission abatements. Hence, international audiences may be greatly interested in observing the impacts of such a policy in Australia. Third, since reverse auctions have been mostly applied at small scales, the methodology or model developed in this study to examine the impacts of reverse auctions at the country level across all sectors would provide a good reference for economic and/or environmental modellers.

Results show that when the Government does not need to recoup the funding allocation (Scenario 1), the effects on the Australian economy are relatively smaller than those in Scenario 2 and Scenario 3 when the Government increases the production tax rates to recoup the budget. However, the impacts of the ERF scheme in all scenarios are relatively small because the funding for emission abatements is small compared to the size of the economy. For example, real GDP only declines by 0.3%–0.4% in all scenarios. This is consistent with previous studies in Australia when studying the impact of a carbon tax or an emissions trading scheme on the Australian economy (for example, see Meng et al. (2013), Siriwardana et al. (2013), Adams et al. (2014), and Nong et al. (2017)). In their studies, the carbon prices are relatively higher than the price in this study, although the effects on the economy in their studies are higher than those in this study by comparing the

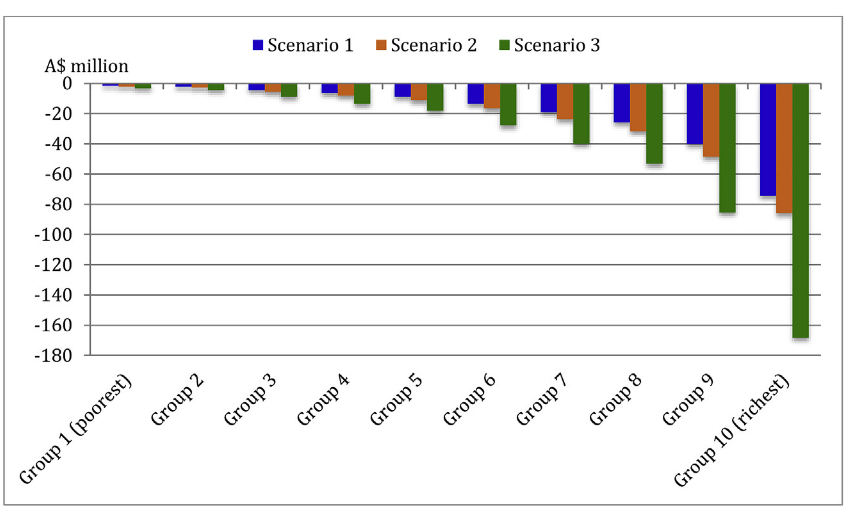

Fig. 3. Equivalent variation compared to the baseline in 2025 (A$ million).

carbon prices. For example, Meng et al. (2013) suggested that Australia would experience a reduction in real GDP by 0.59% when the carbon price is A$23 per tonne of CO_2e, and Nong et al. (2017) showed that real GDP in Australia would decline by 1.6% when the carbon price is A$41 per tonne of CO_2e. Although this study does not directly generate a carbon price, the Government's funding used to buy emission abatements indicates the carbon price that is used to calculate the emission abatements and allocated funding to each sector in this study's simulations.

The results also show that increased production taxes to fulfil the allocated funding based on the amounts of funding allocated to each sector would allow Australia to experience a relatively lower unfavourable impact rather than increasing the production taxes according to the current levels of the production tax rates. However, the effects are only slightly different between these two scenarios (Scenario 2 and Scenario 3). Ideally, the Government does not need to recoup the allocated funding so that the effects on the Australian economy are relatively small (Scenario 1). In all scenarios, while the effects on most sectors are small, outputs and exports of the agricultural commodity are highly unfavourably affected. Households are slightly affected under this scheme and the renewable electricity generation sector experiences a small expansion. The results also found that there would be a need for supportive policies or programs for the agricultural sector because this sector is able to sell a high volume of emission abatements to the Government but it is also considerably affected under the scheme compared to the effects on other sectors. These supportive policies or programs may include providing risk management courses, or reducing consumption taxes on crucial inputs, such as fertiliser and irrigated water, for this sector, or reducing export taxes for agricultural produces.[8]

There are several drawbacks in this study that should be noted. First, it is beyond the ability of the author to collect industrial projections, such as consumptions or output levels, and technology development, for updating the database. Second, some sectors may have higher abatement costs than the average winning price and some have the costs below the average level. However, the real auction prices by each individual sector are not publicly available; hence, this study can only use the average winning price for its examination. This may lead the results provided in this study not to be entirely accurate. However, since the average prices over six reverse auctions are very close to each other and close to the average price of the six auctions, it indicates that they are very competitive auctions, which may result in small differences between the winning prices. In other words, the winning prices may not be highly different from the average winning price. In addition, there may not be high differences in the macroeconomic impacts between applying an average winning price and applying specific winning prices for each sector because the average costs are the same. However, the impacts on sectors may be different but are probably at small different rates due to the aforementioned reasons. Third, the assumption of the expense by each sector on abatement capital is arbitrary, as sectors may have different strategies to spend their funding on investment. If it is adopted, the results on particular sectors may be changed from those in this study, but the differences of the impacts are likely to be small because the investments are relatively small compared to the current capital stock levels. Fourth, the static CGE model used in this study has limitations but this is because the information on the funding allocation and emission abatements over time are not explicitly announced. If such information were known, a dynamic CGE model would be preferred because it can provide more detailed impacts, for example, the impacts over years.

[8] http://www.oecd.org/tad/agricultural-policies/.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2019.01.193.

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